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Modelling of the Adaptive Cycle

Insight into processes in complex systems using abstract modelling

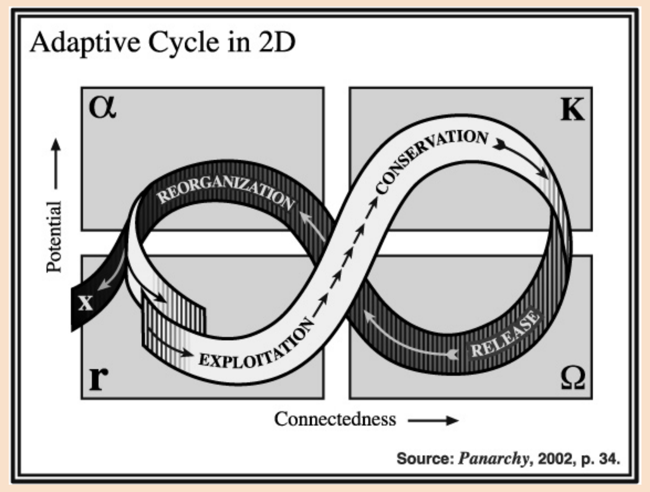

Fig. 1 The Adaptive Cycle metaphor[1] is a model for a sequence of phases often observed in complex systems. It is commonly illustrated with the Möbius strip.

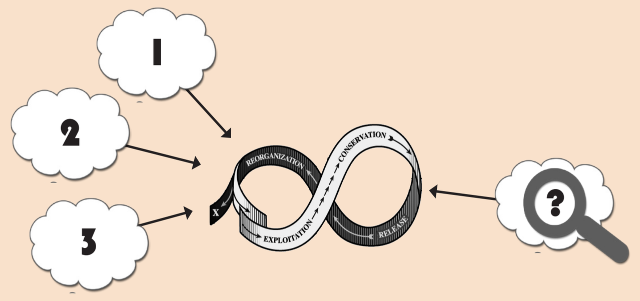

Fig. 2 The Adaptive Cycle is derived from the analysis of many systems (**1, 2, 3**). We ask vice versa: Which features (**?**) must a system have to be describable by the Adaptive Cycle?

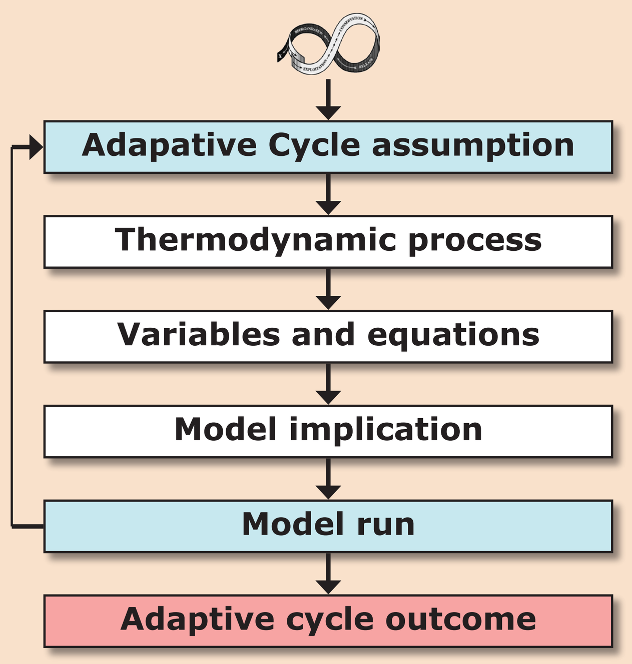

Fig. 3 Our methodological approach is based on an iterative procedure of choosing, transforming and implementing Adaptive Cycle metaphor assumptions into our model.

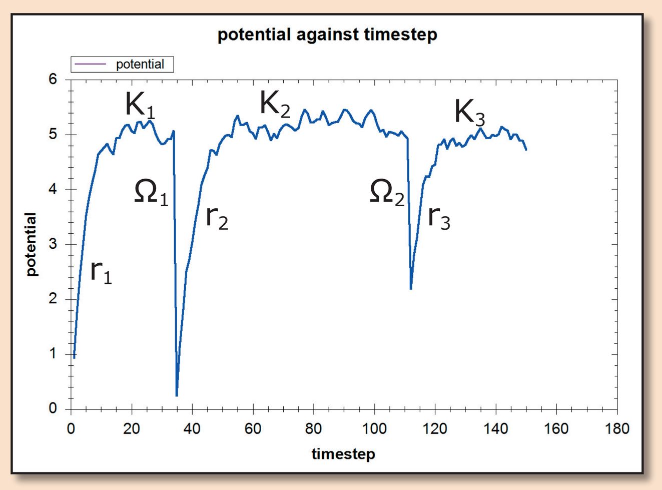

Fig. 4 Considering the key variable *potential* against time reveals the r-, K- and Ω-phases of an Adaptive Cycle. In the example given we could identify 2½ cycles pending the next release event.

Introduction

The Adaptive Cycle metaphor[1] (Fig. 1) can be seen as a black box model for a multitude of complex systems. It describes development and evolution of these systems but only hints at internal processes. The aim of our research is to gain insight into these internal processes which together with analysing historical data can help develop sustainable management strategies.

Hypothesis

Due to the fact that many diverse complex systems have been successfully described through the Adaptive Cycle[2], we hypothesise that their behaviour might be produced by internal processes that are generic to all of these systems. Through the analysis of these generic processes we aim to find out the generic features for a system that can be described with the Adaptive Cycle metaphor (Fig. 2).

Methodology

Our model was developed as a mathematical model in an iterative procedure. We subsequently chose an assumption made within the Adaptive Cycle metaphor and considered a possible underlying thermodynamic process and applied this process to our model as a combination of variables and (differential) equations. Afterwards we computed our model and analysed the results to see if they show any sign of an Adaptive Cycle. If no signs were found, we chose a new assumption (Fig. 3). All processes in our model were to be carried out simultaneously, which particularly meant that the idea of phases present in the Adaptive Cycle was not explicitly transferred to our model.

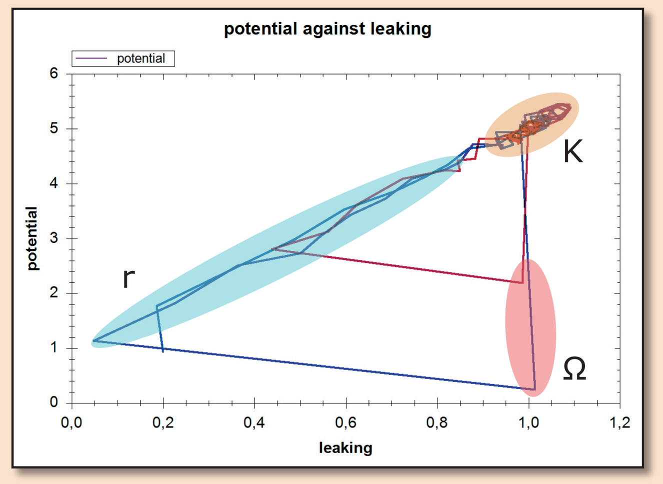

Fig. 5 The *potential* from Fig. 4 plotted against a parameter *leaking* shows typical locations of the Adaptive Cycle phases. Time appears in the diagram as blended line colours from blue to red.

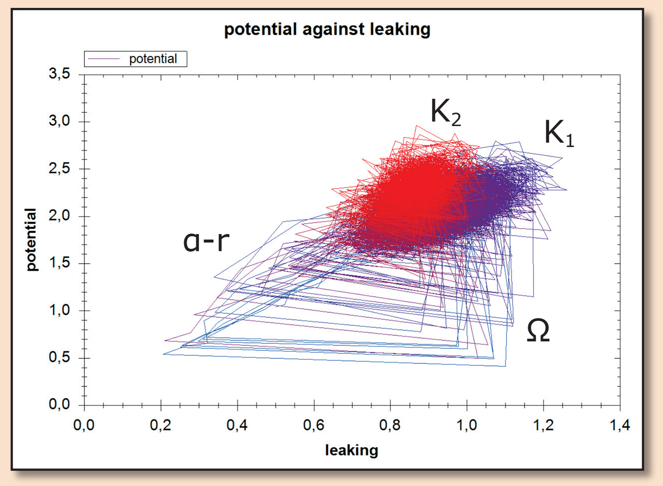

Fig. 6 In our model reorganization cannot be distinguished as a separate phase. It mainly occurs during the r-phase and can lead to several K-phases different in location and shape.

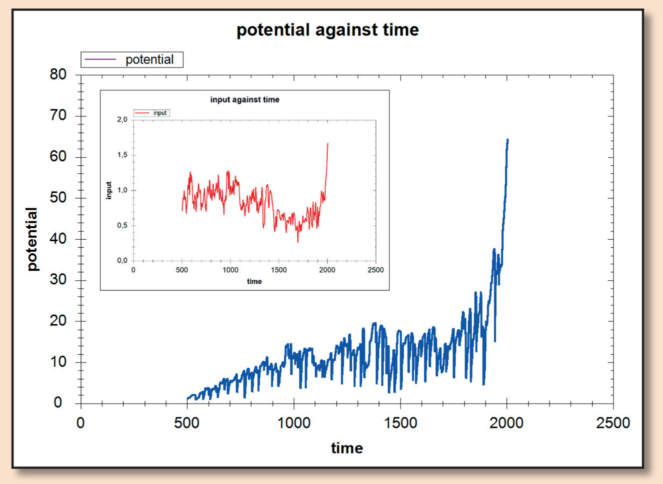

Fig. 7 A possible result of temperature index[3] (red) application to our model is the shown potential curve (blue) which depicts a model system that is able to improve input usage over time.

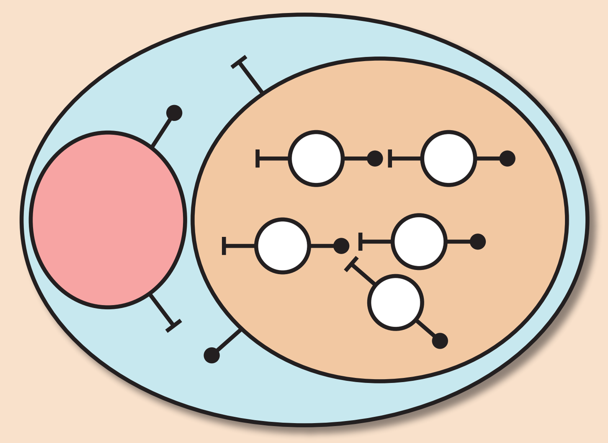

Fig. 8 Our agent-based model which is currently being developed consists of freely associated nested systems which are constituted by self-organisation of their subsystems.

Main results

Our study indicates that a system can be described by an Adaptive Cycle if it at least has the following features: has non-constant input, capability for accumulation and reorganisation, and underlies thermodynamic principles. Although all processes in our model proceeded simultaneously, we could clearly identify the phases of the Adaptive Cycle in the model outcome. This was made possible by analysing the value of key variables (Fig. 4) and distinguishing types of temporal patterns in phase diagrams (Fig. 5). We found out that implementing reorganisation through probabilistic-driven changes of parameters leads to different stable system states (Fig. 6).

Application to real data

We believe that identification of essential features of complex systems through an abstract model can also help to find measures for analysing and understanding past, present or future real-world systems. As a simple illustration we applied our model to a temperature index for the last 1500 years[3] to see if the model can produce reasonable results (Fig. 7).

The next step: Agent Based Model

Although our model, based on differential equations, enabled us to identify key features of complex systems, we could not include all Adaptive Cycle related concepts of our interest. To implement the ideas of Panarchy we started developing an agent based model of nested systems with a high degree of freedom in interactions (Fig. 8). With this new model we hope to gain even more insight into complex systems.

[1] Lance H Gunderson, C. S. Holling, eds., Panarchy: understanding transformations in human and natural systems, First edition 2002, Island Press, Washington.

[2] among others (a) articles in [1]; (b) J.A. Dearing, Landscape change and resilience theory: a palaeoenvironmental assessment from Yunnan, SW China, in The Holocene 18,1 (2008), pp. 117-127; (c) Jianguo Liu, Thomas Dietz, Stephen R. Carpenter, Carl Folke, Marina Alberti, Charles L. Redman, Stephen H. Schneider, Elinor Ostrom, Alice N. Pell, Jane Lubchenco, William W. Taylor, Zhiyun Ouyang, Peter Deadman, Timothy Kratz, William Provencher, Coupled Human and Natural Systems, in Ambio Vol. 36, No. 8, 2007, pp. 639-649.

[3] Michael E. Mann, Zhihua Zhang, Malcolm K. Hughes, Raymond S. Bradley, Sonya K. Miller, Scott Rutherford, Fenbiao Ni, Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia, in Proceedings of the National Academy of Sciences, Vol. 105, No. 36, 2008, pp. 13252-13257.